HELIA, 17, Nr. 20, p.p. 13-20 (1994)

FINDINGS ON SUNFLOWER SELF-FERTILITY IN CONNECTION WITH LINE HYBRIDIZATION

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SUMMARY

Response to various degrees of self-fertilization (geitonogamy and autogamy) was compared in 6 lines with various leveles of self-fertility and in their crosses.

Incidence of lines with a high level of self-fertility at geitonogamy is considerable, self-fertile lines are rare at autogamy. Crosses of geitonogamic self-fertile lines display a lower self-fertility at autogamy than their parents.

Result of crossing is influenced among other factors by specific combination ability of lines in this trait.

Key words: Sunflower, self-fertility, geitonogamy, autogamy

INTRODUCTION

Self-fertility of sunflower lines, as well as of hybrids, belongs to the most important traits from the viewpoint of breeding. It is a decisive factor for yield, particularly under less favourable weather conditions at flowering and in areas lacking sufficient amount of pollinating insects.

Several foreign papers characterize the subject as topical. According to Vranceanu et al., (1978) genetic influence on self-fertility is very complex and enviromental factors have a big share in its meterialization. In F1 generation expression of partial dominance prevails. Fich (1983) points to a very broad variability among sunflower lines from completely self-fertile to almost zero self-fertility. Segala et al., (1980) express the heritability of self-fertility by means of regression between parents and hybrids by coefficient 0.26 which can be taken rather for a lower degree of heritability. Barlov, Krutko (1987) found basic difference in inheritance of self-fertility materialized by autogamy (self-pollination on one flower) and geitonogamy (pollination among flowers in one head). In geitonogamy intermediarity or partial dominance manifests in F1 generation. In autogamy self-fertility is mostly of recessive character.

This paper deals with those research results which can be of interest in sunflower breeding. The other part will be used as a contribution to the study of inheritance of self-fertility.

MATERIAL AND METHODS

Six sunflower lines and hybrids of selected combinations of them were used as the material.

Four lines were original D-34-2-10 from France, HT 23c and AC-84-1015 B from Romania and sterility maintainer was the well-know cms line HA 89 from the USA.

Two lines were developed by inbreeding selected plants from the Yugoslav hybrid NS-H-33 RM and from the American varietal population Sundak, of confection type.

For simplification in the subsequent text, the lines are designated as follows:

D-34-2-10	designated	D
HT 23c	"	HT
AC-84-1015B	"	AC
HA 89	"	HA
NS-H-33 RM	derived	NS
Sundak	derived	SU

Before the proper experiments, the lines HT and SU were tentatively evaluated as little self-fertile, NS and D as medium self-fertile, AC and HA as highly self-fertile.

Crossing-scheme was elaborated as follows:

HT x SU -	combination	little x little	self-fertile
HT x NS -	"	little x medium	"
HT x AC -	"	little x highly	"
NS x D -	"	medium x medium	"
NS x AC -	"	medium x highly	"
AC x NA -	"	highly x highly	"

In the experiment, 3 ways of pollination were used (4 ways for the lines).

The check variant (way of pollination) was represented by free pollination by means of insects. Not only pollen of the mentioned lines and hybrids but also of other sunflower plants used in the other experiments conducted at the same plot was available.

The second variant of pollination was self-fertilization of flowers within one head (geitonogamy) when pollen of the isolated head was transferred mechanically by a cotton wad.

The third variant of pollination was self-polination of single flowers (autogamy) which was materialized by isolating the head without any additional treatment. In the case of the lines, fourth variant of pollination can be described, namely legitimate cross-fertilization when pollen of a selected accurately defined partner is transferred on stigmata of an emasculated flower. The F_0 generation was originated in that way (hybrid seed on mother plant).Besides the parental generation P, the generations F_0, F_1 (proper hybrid) and F_2 were used. The generation F_2 was obtained by geitonogamy from plants of the F_1 generation.

Extent of self-fertility was evaluated according to the proportion of fertilized achenes (expressed in %) of the total number of achenes in the head after geitonogamy and also autogamy in the lines, hybrids of the F_1 and F_2 generations. With regard to a possible influence of weather factors on pollination and fertilization, the trial was repeated for 3 consecutive years at one locality (Prague-Ruzyne, Czech Republic) without plot replications because the influence of plot variability on the expression of self-fertility cannot be assumed. According to the experience gathered over several years, the conditions at the experimental locality are very good for sunflower pollination. The presented results are 3-year average values of the proportion of fertilized achenes.

RESULTS

Reactions of lines to various ways of fertilization

A set of 6 lines differing in seed set ability at various ways of fertilization (Table 1) was used.

Generally, poorer seed set was ascertained in the line HT, that displayed only 31% full achenes on the average of all 4 fertilization ways. Other 3 lines (SU, D and NS) showed in general a medium ability to set full achenes (average of all 4 fertilization ways varied between 57.6 and 61.3%). Two lines (HA and AC) displayed generally good seed set of full achenes, 71.1-71.5%. Average seed set of achenes of all 6 lines was 69% at free pollination, 64% at geitonogamy, 56.5% at directed pollination with a certain pollen (crossing) and 45% at autogamy. Hence the difference between free pollination and geitonogamy was only 5% (4 out of the 6 lines displayed a high level at geitonogamy (70-80%), one line medium level (55%), one line low level (30%). The 4 lines with a high level of seed set of full achenes after geitonogamy displayed a lower proportion of full achenes after crossing; on the other hand, 2 lines with medium or low level of self-fertility showed an increased seed set of full achenes after crossing. Seed set after crossing was relatively well-ballanced (46.5-68.8%, difference 22.3%), at free pollination 40.6-85.4%, i.e., difference 44.8% hence doubled, at geitonogamy 30.0-80.6%, i.e., difference 50.6% and at autogamy 8.2-74.9%, i.e., difference 66.7%. The largest differences between the lines were at autogamy, next at geitonogamy, then at free pollination and the smallest at crossing.

Table 1. Response of lines to various ways of pollination

Line	V.S.	G.	A.	Ø	X	Ø (in %)
HT	40.64	29.97	8.18	26.26	46.50	31.32
SU	62.23	54.95	44.24	53.81	68.85	57.57
NS	73.66	69.98	51.74	65.13	50.04	61.35
D	69.66	70.30	35.42	58.46	63.64	59.75
HA	84.20	80.57	74.90	79.89	46.48	71.53
AC	85.38	80.53	55.01	73.64	63.72	71.63
Ø	69.29	64.38	44.91	59.53	56.53	57.03

Legend: V.S. - free pollination
G - geitonogamy
A - autogamy
X - legitimate pollination

A distinct difference appeared when autogamy was compared with geinogamy, i.e., 19.5%, and even a larger difference was found when autogamy was compared with free pollination, i.e., 24.4%.

Utilization of legitimate fertilization with alien pollen (crossing) offers a somewhat lower seed set (7.8%) than geitonogamy which is affected by the fact that the majority of lines is inclining to self-fertility. In comparison with free pollination, the legitimate outcrossing is by almost 13% less successful.

Single lines show various responses to free pollination, legitimate outcrossing, geitonomagy and autogamy. The poorly fertile HT line shows fertility decrease of 11% as a response to geitonogamy and a decrease of almost 33% as a response to autogamy

compared with free pollination. Crossing causes in this line an increased portion of fertilized achenes, by 38% compared with autogamy, 16.5% compared with geitonogamy and 6% compared with free pollination.

All other lines react to geitonogamy by slight decrease of the portion of fertilized achenes in comparison with free pollination, namely, from 0 to 7%. Response to autogamy is much more variable. Compared with free pollination, the proportion of fertilized achenes decreased in the line SU by 18%, NS by 22%, AC by 30%, and D by 34% (the last line tolerates geitonogamy the best). Only in the line HA the decrease of the portion of fertilized achenes was lower than 10%.

It is obvious that most of the lines studied have a good seed set after fertilization among flowers within one head, when combined with mechanical pollen transmission and stigma irritation, whereas pollination with the pollen of the same flower without mechanical aid almost always leads to a sharp decrease in the proportion of fertilized achenes.

The line SU displayed a positive reaction to legitimate outcrossing, by 14% compared with geitonogamy, 7% compared with free pollination. The other 4 lines (inclining to self-fertility) give a negative response to crossing; line D reacts by a decrease of the proportion of fertilized achenes by 6%, other 3 lines by a decrease by 22-38% compared with free pollination and by a decrease by 17-34% compared with geitonogamy. Line HA offers an even higher proportion of fertilized achenes after autogamy than after crossing, namely by 28.5% (in the case of this line the proportion of fertilized achenes in autogamy is extremely high, i.e., 75%, whereas after crossing it is the lowest of all lines, namely, only 46,5%).

Line HA achieves the highest values at autogamy and geitonogamy, namely 75% and 80.6%, respectively; line AC achieves the highest values at free pollination, 85.4%, and line SU after crossing, 68.8%. The lowest values after autogamy, geitonogamy, as well as after free pollination are displayed by the line HT, 8.2%, 30% and 40.6%, respectively, and after crossing by the line HA, 46.5%.

In general, an evident trend to decrease of the proportion of fertilized achenes from free pollination through geitonogamy to autogamy can be observed. Crossing is ruled out of that trend and its effect on the increase of the proportion of fertilized achenes depends on the inclination of the line to self-fertility.

Expression of consequences of various ways of pollination on the hybrids

Average proportion of fertilized achenes of the parents of the 6 crosses developed by various ways of pollination includes a broad scale of ascendant values (Table 2).

Table 2. Average of parents (data from Table 1) of single hybrid combinations

Line	V.S.	G.	A.	Ø
SU a HT	51.43	42.46	26.21	40.03
NS a HT	57.15	49.98	29.96	45.70
AC a HT	63.01	55.25	31.59	49.95
NS a D	71.66	70.14	43.58	61.79
NS a AC	79.52	75.26	53.38	69.39
AC a HA	84.79	80.55	64.96	76.77

The lowest value was manifested by the average of the parents of the hybrid SU x HT at autogamy, 26.2%, the maximum value by the hybrid AC x HA at free pollination, 84.8%.

For autogamy the spread of the average of the parents of the hybrid combinations is 26.2-65%, at geitonogamy 42.5-80.6%, and at free pollination 51.4-84.8%. The ranking of the average of the parents from the lowest to the highest for all three ways of pollination is SU x HT, NS x HT, AC x HT, NS x D, NS x AC, AC x HA.

The hybrids in the F_1 generation displayed a high proportion of fertilized achenes (Table 3a) at free pollination as well as at gietonogamy. The spread was 78,9-89,3%. Hence the difference between the minimum and the maximum value reached only 10,4%. At geitonogamy, the spread was 63.5-85.5, hence, somewhat higher, i.e., 22%; however, this value was lower than 76% only in one hybrid, NS x HT, while the spread of the other 5 hybrids was only 9,5%.

Table 3. Response of hybrids to various ways of pollination

Hybrid F_1	V.S.	G.	A.	Ø	F_2	V.S.	G.	A.	Ø
SU x HT	78.88	79.56	59.06	72.50		67.59	63.65	53.89	61.71
NS x HT	83.75	63.46	37.14	61.45		67.73	52.69	42.65	54.36
AC x HT	79.60	77.89	72.30	76.60		70.22	69.78	62.21	67.40
NS x D	89.33	80.55	31.02	66.97		74.18	79.34	68.88	74.13
NS x AC	88.13	75.99	40.12	68.08		74.81	75.40	65.35	71.85
AC x HA	83.82	85.48	78.55	82.62		81.66	65.09	52.71	66.49
Ø	83.92	77.16	53.03	71.37		72.70	67.66	57.61	65.99

A distinct difference between the hybrids appeared at autogamy. The minimum value reached 31%, the maximum 78.5%, the difference is 47.5%.

On the whole, the differences in the three ways of pollination were clearly lower between the F_1 hybrids than between the lines, particularly at free pollination and at geitonogamy.

In single hybrids, very different responses to various ways of pollination were observed.

The hybrids of the lines AC x HT and AC x HA (then both with participation of the line AC) did not react to various ways of pollination. Decrease of the proportion of fertilized achenes was practically not changed due to geitonogamy compared with free pollination and at autogamy it was lower, only by 5% and 7%, respectively.

The line AC did not decrease much the value of pollination at autogamy, but it did distinctly react to autogamy. Of complementary components, HT reacted clearly by the decrease of the value at geitonogamy, as well as at autogamy. On the contrary, HA reacted less distinctly to the both degrees of limitation of free pollination.

A very significant decrease between free pollination and geitonogamy was observed in the hybrid NS x HT (20.3%), only a little lower in NS x AC (12.1%); the same situation but in a higher degree manifests at autogamy, where the mentioned hybrids show the decreases of 47% and 48%, respectively, and the combination NS x D the decrease by 58%. It is obvious that in hybrids having the line NS as one component distinct response to geitonogamy and autogamy can be observed that considrably overcomes the decreases in the lines themselves. Nevertheless, the line NS shows the highest decrease of the

proportion of fertilized achenes neither at geitonogamy nor at autogamy. However, the three complementary parental lines show a trend to a distinct negative response to autogamy (30-34%) but not to geitonogamy.

The line HT exhibits its trend to respond negatively to the limitation of free pollination in combination with the line NS. A similar response can be observed also in the lines D and AC in combination with NS. The line NS enables the expression of negative responses to self-pollination in the other lines.

The line HT in combination with AC cannot express its negative response to self-pollination and the same is true for AC in that combination. Similar situation is in the combination HA with AC, where probably the positive effect of the line HA, as the prevailing component, is expressed. Out of the 3 lines that appear in the trial in more combinations, the line NS is decisive for materialization of the expression of its partner, without realizing its own level of the trait. The lines HT and AC realize their level of the trait more in dependence upon the partner and in mutual combination their negative manifestation is mutually eliminated so that it becomes positive.

Combination	Decisive line	Line expression
SU x HT	none	rather SU
NS x HT	NS	HT
AC x HT	none	reverse in both
NS x D	NS	D
NS x AC	NS	AC
AC x HA	none	rather HA

F_1 hybrids usually show distinct increases in the proportion of fertilized achenes in comparison with the average of their parental lines.

In the case of free pollination, the increases were by 17-27% except the combination NS x AC, where the excess from the average of the parents was only 8.6% and in the combination AC x HA, where the average of the parents was not exceeded (however, its value is very high, 84.8%). In the case of geitonogamy the excess is by 10-37%, again except in the two combinations mentioned before. At autogamy, considerable diversification appeared. Two combinations distictly exceed the average of their parents, namely, AC x HT by 10.7% and SU x HT by 32.8%; on the contrary, the combinations NS x D and NS x AC have the value of the proportion of fertilized achenes at autogamy by 12-13% lower than the average of their parents.

In the F_2 generation, lower values than in the F_1 generation have been obtained in general (Table 3b): at free pollination by 11.2% and at geitonogamy by 9.5%, decreases being found in all combinations.

In the case of autogamy, some combinations in the F_2 generation had a higher value then in the F_1 generation, so that the average of all hybrids in the F_2 generation was by 4.6% lower than in the F_2 geheration.

At free pollination, the values varied in the range 67,6-81,7% (difference 14.1%), at geitonogamy 52.7-79.3% (difference 26.6%), and at autogamy 42.6-68.9% (difference 26.3%). Except for autogamy where the range between the hybrids in the F_2 generation was much smaller (almost by a half) than in the F_1 generation, a similar situation was observed in both hybrid generations. In the reaction of the F_2 hybrids some deviations appeared in comparison with the F_1 generation. The combination AC x HA in the F_2

generation showed a high decrease of the proportion of fertilized achenes (by 16.6% due to geitonogamy and by 29% due to autogamy) whereas in the F_1 generation this decrease was minimum.

On the contrary, the hybrids NS x AC and NS x D, that showed a low decrease of the value due to geitonogamy as well as autogamy, namely 5-9%, displayed a very high decrease in the F_2 generation, namely 48-58%. Unchanged situation due to the prevalence of free pollination was found in the F_1 and F_2 generations of the combinations SU x HT, NS x HT and AC x HT. In the hybrids having HT as one component, the responses to self fertilization following the generation after crossing was low (hybrids in the F_1 and F_2 generations behaved similarly, either in negative or in positive direction). In the remaining three combinations, self-fertilization had a positive effect on the decrease of response to further self-fertilization in the following generation, in two cases in one combination, namely AC x HA, previous self-fertilization caused a distinct negative response to further self-fertilization. Which combination of lines has the highest inclination to self-fertility is undecided. Obviously, the most self-fertile line, HA, manifests a negative response (because AC in combination with NS has a completely reverse response). The line HA has the average value of the trait with the ways of pollination 71.5% the F_1 hybrid in which it participates reaches 82.6% (in both cases the highest value), at free pollination in the F_2 generation it is 81.7% (again the highest value), but due to geitonogamy only 65% (average) and after autogamy only 52.7% (almost the lowest value), In the F_2 generation, only the hybrid AC x HA showed a decrease of the value of the trait as compared with the average of the parents.

CONCLUSIONS

1) Difference in the set of full achenes in self-fertile lines at free pollination and at geitonogamy is minimum, whereas at autogamy it is very distinct with some exceptions. Self-fertile lines usually tolerate geitonogamy well, but only rarely do not show a negative response to autogamy.

2) Free (uncontrolled) pollination and geitonogamy are suitable for self-fertile lines, less suitable is pollination by crossing (legitimate pollen) and autogamy.

3) In the F_0 generation, self-fertile lines have a lower proportion of fertilized achenes than at geitonogamy. In non-self-fertile lines in the F_0 generation, the proportion of fertilized achenes is higher than at geitonogamy. Therefore, differences between self-fertile and non-self-fertile lines are small in the F_0 generation.

4) At geitonogamy, F_1 crosses between self-fertile or non-self-fertile lines achieve a higher proportion of fertilized achenes than is the average of parental lines, and higher or almost identical values to those shown by the self-fertile parent.

At autogamy, hybrids of self-fertile lines usually have lower values of the proportion of fertilized achenes than parental lines.

5) The crosses of the F_1 generation of self-fertile and non-self-fertile lines differ amont themselves less than the lines themselves.

6) At autogamy of a hybrid whose one parent is only partially (medium) self-fertile and the second parent non-self-fertile, the influence of the latter line is more pronounced. In a hybrid of a highly self-fertile and a non-self-fertile parent, the influence of the former line is more pronounced. The second case is substantially less common because of rare incidence of self-fertile lines at autogamy. Cases also occur when at autogamy a hybrid

of two non-self-fertile lines shows a higher self-fertility than either parent (which also shows the importance of specific combining ability in this trait).

7) A hybrid of two self-fertile lines is usually also highly self-fertile. Therefore, its self-pollination does not cause increase in the proportion of unfertilized achenes. However, plants grown from seeds originated in the above mentioned way (F_2) can show a lower self-fertility in respect to not only the hybrid but also both parental lines.

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RESULTADOS SOBRE AUTOFERTILIDAD EN GIRASOL EN CONEXION CON HIBRIDACION ENTRE LINEAS

RESUMEN

La respuetsa a varios grados de autofertilización (geitonogamia y autogamia) se comparó en seis líneas con varios niveles de autoferdilidad y en sus cruses.

La incidencia de líneas con un alto nivel de autofertilidad y geitonogamia es considerable, y las líneas autofértiles son raras en autogamia. Los cruses de líneas autofértiles geitonogamicas mostraron una autofertilidad mas baja en autogamia que sus padres.

Los resultado de cruses está influenciado entre otros factores por la aptitud combinatoria especifica de las líneas para esta caracter.

CONTRIBUTIONS SUR L'AUTO-FERTILITÉ DU TOURNESOL RELATIVE À L'HYBRIDATION ENTRE LIGNÉES

RÉSUMÉ

Six lignées caractériseés par divers niveaux d'auto-fertilité et le produit de leur croisement ont permis la comparaison de la réponse à divers degrés d'auto-fertilité (geitonogamie et autogamie) chez le tournesol.

L'incidence de lignées à haut degré d'autofertilité de type geitonogame est considérable, les lignées auto-fertile de type autogames sont rares. Les croisements de lignées auto-fertiles geitonogamiques donne lieu à des niveaux d'auto-fertilité à autogamie moindre que les lignées parentales.

Le produits de croisements est influencé entre autres facteurs par l'abilité à la combinaison spécifique des lignées pour ce caractére.